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SURFACE DRIVEN WELL PUMP

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SURFACE DRIVEN WELL PUMP

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] Embodiments of the present invention generally relate to the field of fluid extraction from bore holes. More particularly the present invention relates to artificial lifting devices and methodologies for retrieving fluids, such as crude oil, from bores where the fluid does not have sufficient hydrostatic pressure to rise to the surface of the earth of its own accord. More particularly still, the present invention relates to the field of recovery of such fluids, where the fluid temperature of the fluids in the wellbore exceeds the temperature at which the sealing materials in the pump rapidly deteriorate, to the point of failure.

Description of the Related Art

[0002] The recovery of fluids such as oil and other hydrocarbons from bore holes, where the fluid pressure in the bore hole is insufficient to cause the fluid to naturally rise to the earth's surface, is typically accomplished by the pumping of fluid collected in the bore hole by mechanical or fluid mechanical means. Several methodologies are known to provide this pumping action, each with its own limitations.

[0003] In one methodology, a rod extends down the well from a surface location to terminate in a production zone of a well, where it is connected to a rod pump. The rod pump generally includes a piston and piston-housing configuration, selectively ported to the well fluid production zone, and production tubing extending from the pump to the earth's surface. The rod is attached to the piston, and it reciprocates upwardly and downwardly, such that during a down stroke thereof, well fluids received in the pump housing are compressed and ported to a production tube, and during the upstroke, a check valve opens and allows well fluids into the piston cavity to be compressed on the next down stroke. Thus the recovery rate is dependant upon the stroke of the rod and the number of strokes of the rod per unit

of time. This type of pump is typically used where the flow requirement of the pump is relatively low. These pumps are most effective for pumping medium to light clean oil but they lose efficiency as the oil viscosity increases, and they experience rapid wear if the pumped fluids contain abrasive media.

[0004] A second methodology is the use of a rotary positive displacement pump, typically called a progressive cavity pump. These pumps typically use an offset helix screw configuration, where the threads of the screw or "rotor" portion are not equal to those of the stationary, or "stator" portion over the length of the pump. By insertion of the rotor portion into the stator portion of the pump, a plurality of helical cavities is created within the pump that, as the rotor is rotated with respect to the pump housing, cause a positive displacement of the fluid through the pump. To enable this pumping action, the surface of the rotor must be sealingly engaged to that of the stator, which also typically is an integral part of the housing. This sealing provides the plurality of cavities between the rotor and stator, which "progress" up the length of the pump when the rotor rotates with respect to the housing. The sealing is typically accomplished by providing at least the inner bore or stator surface of the housing with a compliant material such as nitrile rubber. The outermost radial extension of the rotor pushes against this rubber material as it rotates, thereby sealing each cavity formed between the rotor and the housing to enable positive displacement of fluid through the pump when rotation occurs relative to the rotor-housing couple. Rotation of the rotor relative to the housing is accomplished by extending a rod, rotatably driven by a motor at the surface, down the borehole to connect to one end of the rotor exterior of the housing. At the lower end of the pump, an inlet is formed, and at the upper end of the pump, production tubing extends from the pump outlet to a receiving means on the surface, such as a tank, reservoir or pipeline. Because of the compliant and durable stator, progressive cavity pumps are more tolerant of viscous and abrasive fluids than other pump types.

[0005] One issue encountered with progressive cavity pumps is degradation of the pump components at high temperatures. To operate effectively over a sustained

period of time, the compliant seal between the rotor and housing must maintain its resiliency. The material used for effectively forming this seal, typically nitrile rubber, encounters temperature-based resiliency breakdown if the ambient to which the material is exposed exceeds approximately 250 degrees F. Thus, in fields with naturally occurring high downhole temperatures and in fields where steam injection is used to free heavy oil, such as tar sand, from the formation, the temperature of the oil will often exceed the 250 degree F threshold, and rapid pump degradation will occur. Although other sealing materials have been used to form the rotor-to-pump seal, they are compromises in terms of either performance or cost, and thus have received limited success in the marketplace.

[0006] A third artificial lift methodology is the use of the electric submersible pump. These pumps typically are composed of a multi-stage centrifugal pump attached to an electric motor that is located in the wellbore. The motor is located immediately below the pump, with a rotary drive shaft running up from the motor through a seal that prevents the entry of wellbore fluid into the motor. The pump is normally located near the bottom of the well, proximate the production zone, with the inlet at the lower end, and the outlet at the upper end of the pump, discharging into the production tubing. An electrical power cord from the surface is clamped to the outside of the production tubing and the pump, so that it can deliver power through the annulus of the wellbore, to the motor. In high temperature pumping applications such as those mentioned above, the temperature of the well plus the normal temperature rise of an electric motor tends to cause thermal breakdown of the electrical insulation, causing failure of the motor or the wiring. As a result, the use of this artificial lift method is limited to wells having a moderate temperature. Although there is the possibility of driving such pumps from the surface, through a rod rotating about its longitudinal axis, the applicability of such an arrangement is limited by the tendency of the rod to whip or whirl as it is rotated at the 3000 to 4000 rpm's necessary to drive a centrifugal pump. This whirling phenomenon is caused by imbalances in the drive rod, by twist and relax effects as the rod is spun, and by natural vibrations occurring as the harmonic natural frequency of the rod is

approached. As a result, surface driven centrifugal pumps are limited to very shallow fluid recovery applications, typically below 500 feet deep.

[0007] A further method of wellbore fluid recovery is known as jet pumping. This methodology takes advantage of the venturi effect, whereby the passage of fluid through a venturi causes a pressure drop, and the oil being recovered is thereby brought into the fluid stream. To accomplish this in a well, a hollow string is suspended in the casing to the recovery level, and a venturi is provided in a housing adjacent an orifice which extends into the oil in the bore, a fluid is flowed down the string and through the venturi and thence back out the well in the space between the string and casing. The oil is pulled into the stream and carried to the surface therewith, whence it is separated from the fluid. The fluid is recycled and again directed down the well. This technique suffers from poor system energy efficiency and the need for extensive equipment at the surface, the cost of which typically exceeds the value of the oil which may be recovered. Jet pumping is less effective with viscous fluids than with lighter fluids because it is more difficult for a venturi effect to pull viscous fluids into the jet pump mixing tube, and the mixing tube must be substantially longer to accomplish adequate fluid mixing in the pump.

[0008] An additional method of wellbore fluid recovery is gas-assisted lifting, in which natural gas is compressed at the surface and made to flow through the annulus between the production tubing and the well casing to the lower portion of the well, where it is injected through an orifice into the production tubing. The addition of this gas to the liquid in the production tubing reduces the density of the hydrostatic column of produced fluid so that the natural pressure of the formation is then adequate to drive the produced fluid to the surface. This technique suffers from the fact that uniform mixing of the gas with the fluid in the production tubing is more difficult to achieve in viscous fluids. Gas-assisted lifting is further limited by the fact that it depends upon there being adequate pressure in the reservoir to lift the hydrostatic column of reduced density fluid to the surface.

[0009] Therefore, there exists in the art a need to provide enhanced artificial lifting methods, techniques and apparatus, having a greater return on investment and or durability.

SUMMARY OF THE INVENTION

[0010] The present invention generally provides methods, apparatus and article for the improved artificial lifting of fluids, particularly useful in harsh environments, using a centrifugal pump directly driven from a location remote from the downhole location, such as the well head.

[0011] In one embodiment, a centrifugal pump, having at least one rotary component, is driven from a wellhead or other remote location. The drive mechanism includes a drive rod, which extends from a surface driven motor to a downhole location, and a damping member configured to reduce oscillations or other vibrations in the driving rod, and thereby prevent disabling vibration or whirling of the drive rod and/or interference between the rod and fluid recovery tube which would otherwise lead to the failure of one or the other. Furthermore, the invention enables the full torque and power input of the remotely positioned motor to drive the pump, without the need to position the motor downhole or to provide intermediate reduction and step up gear boxes.

[0012] In a preferred embodiment, the rod is extended through a damping sleeve, between which is disposed a dampening medium. Preferably this dampening medium is a lubricating material, such as an oil, which serves to both absorb energy from the turning rod, particularly energy created by lateral vibration, mass non-uniformity or other source of induced energy, as well as provide a pliable medium between the rod and sleeve which forms a physical barrier there between, to prevent or at least significantly reduce the interfering contact between the rotating rod and the sleeve through which it extends.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] So that the manner in which the above recited features of the present invention can be understood in detail, a more particular description of the invention, briefly summarized above, may be had by reference to embodiments, some of which are illustrated in the appended drawings. It is to be noted, however, that the appended drawings illustrate only typical embodiments of this invention and are therefore not to be considered limiting of its scope, for the invention may admit to other equally effective embodiments.

[0014] Figure 1 is a sectional view of a wellbore, including a partial sectional view of the pump support structure, extending into the borehole;

[0015] Figure 2 is a partial longitudinal sectional view of one embodiment of the pump of this invention, Figure 1, showing the pump in a downhole location;

[0016] Figure 3 is a sectional view of the pump of Figure 2 at 3-3; and

[0017] Figure 4 is a schematic view of a wellhead for use with the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0018] The present invention provides methods and apparatus enabling the use of centrifugal pumps in deep boreholes, i.e., those of at least 500 feet depth, without the attendant problems of whirling or whipping as experienced in the prior art, and without the need to locate the pump motor in a downhole location. Referring to Figure 1, there is shown, in schematic representation, a producing oil well having a borehole 10 extending from a wellhead 12 at the opening of the borehole 10 to the earth's surface 14 to a lower terminus 16. The lower terminus 16 of the borehole 10 includes a production zone 18, although a plurality of production zones may be present. Where multiple production zones are present, they are typically isolated by opposed packers (not shown), as is well known in the art.

[0019] Each production zone 18 includes casing 20, which lines the borehole 10 (typically lining the borehole over the entire length of the borehole 10) and which includes holes 24 extending therethrough at the production zone 18 which allow oil or other hydrocarbons from a production zone 18 in the earth adjacent the borehole 10 to flow into the borehole 10. The production zone 18 may be screened, i.e., a cylindrical screen may be located between the interior of the production zone 18 and the holes 24, to reduce the incidence of sand flowing therein from the formation, and may also be isolated from the remainder of the wellbore 10 by packers (not shown) placed above and below the production zone 18, which is well known in the art. As the fluid flowing into the well from the producing zone 22 accumulates therein, it forms a pool of recoverable fluid in the well, which may be replenished as the fluids are removed from the production zone 18. However, the fluid in the production zone 18 exists at a pressure similar to that of the formation from which it is collected, which pressure is typically insufficient to naturally hydrostatically drive the oil to the well head location.

[0020] Within this production zone 18 is disposed a surface driven centrifugal pump 26, as best shown in section in Figure 2. This pump 26 includes an outer housing 28, within which is formed a diffuser cavity 30 within which an impeller 32 is rotatably driven by a drive rod 34. Impeller 32 typically includes a plurality of vanes 36 which impart momentum/velocity to the fluid, when the impeller is rotated about its axis within the diffuser cavity 30. The interaction of the fluid with the diffuser cavity converts this velocity to pressure. As shown schematically in Figure 1, pump 26 also includes fluid inlet 38 and an outlet 40 ported to tube 54 for pumping of fluids up the well to the surface. A pump housing 28/impeller 32 combination, as described, typically cannot impart sufficient momentum to well fluids to cause them to be lifted to the earth's surface from a location deep in a borehole 10. Therefore, pump 26 typically includes a plurality of such pump housings 28 and impellers 32, the outlet 36 of each housing 28/impeller 32 combination passing into and forming the inlet 38 of the next housing 28/impeller 32 combination, until the momentum of the fluid leaving the last, uppermost pump housing is sufficient to propel the well fluid up the well to the well head 12. Preferably, the pump housings 28 are aligned

such that the centerlines of each of impellers 32 are collinear, and the lowestmost housing 28 in the wellbore has the opening 38 opening for receiving well fluids therein, and the uppermost pump housing 28 has an outlet 40 for pumping the fluids to the well head 12. Furthermore, each pump housing 28 is configured to enable the interconnection of each impeller 32, such that all impellers 32 in the connected stack of impellers 32 are driven by a single drive rod 34 suspended from the earth's surface. Preferably, each impeller includes a central hub 41, having a plurality of blades 43 extending therefrom. Hub 41 includes a recessed female portion 45, into which, for the uppermost impeller 32, splines of the drive rod 34 may be received, and a splined male portion 57, which extends into the female portion 45 of the next below impeller 32, to enable common rotation of each impeller 32. Typically, pump 26 will include sufficient impeller 32/diffuser cavity 30 combinations, such that each combination in the stack, other than the lowermost housing which initiates receipt of the well fluids, and the uppermost housing 28 from which the well fluid is directed to the surface, supply the well fluid at an incrementally higher pressure into the next adjacent impeller 32/diffuser cavity 30 combination, such that the well fluid leaves the uppermost housing 28 at a pressure sufficient to reach the surface. Typically, up to several hundred such housings 28 will be strung together to provide the pumping of the fluid from the wellbore 10.

[0021] Referring to Figures 1 to 3, the pump 26, shown schematically, is suspended in the well at the end of a sleeve 54 which extends from the well head at the opening of the well into the earth downwardly in the well to the recovery zone, such that the uppermost outlet 40 of pump 28 is sealingly engaged and in fluid communication with the inner circumference of sleeve 54. Preferably, the lower end of sleeve 54 is threaded, and is received into a threaded aperture or over a threaded boss 48 on pump housing 28. Extending within sleeve 54 is pump main drive rod 34 which extends from the wellhead and into coupled engagement with the impeller 32 of the uppermost pump housing 28. This coupling is provided by configuring the drive stem inlet of housing 28 as a female spline coupling connection, having a plurality of generally longitudinal splines therein (not shown), and the drive rod 34 includes, at its lower terminus, a mating male spline connection 57 which is received

in the female spline coupling. This drive stem is coupled to the impeller 32 of the uppermost housing, such as by configuring impeller 32 to include an extending stem portion which extends through the housing 28 and is sealed against leakage but to enable rotation, such as with a wiper seal. The structure and operation of centrifugal pumps for downhole operation and placement is well known to those skilled in the art.

[0022] The passage of the pump main drive rod 34 through sleeve 54 forms an annulus 60 therebetween, within which is maintained a supply of lubricant 62, such as oil or other fluid. Preferably, the lubricant has sufficiently high viscosity to serve as a damper or energy absorbing media, yet sufficiently low viscosity such that it does not significantly absorb power from the motor driving the rod 34 and thereby require excessive power requirements and heating of the lubricating oil in situ. A lubricant such as 30 wt. motor oil, or a lubricating oil of similar viscosity, is specifically contemplated to meet these requirements. The lubricant 62 is preferably maintained within the annulus 60 at all times, and thus a seal 64 is maintained between the pump main drive rod 56 and the sleeve 54 at the well head, and the coupling between the sleeve 54 and uppermost pump housing 28 seals the lowermost end of the annulus 60. However, it is specifically contemplated that the lubricant may leak from the annulus or be otherwise consumed, and thus a source of lubricant replenishment is provided at the wellhead.

[0023] During operation, main pump drive rod 34, although rotating at speeds at which, in the prior art, vibration whipping and/or whirling would occur which would cause failure by high speed interfering contact between the rod and the production tubing, operates successfully when encased in lubricant in a sleeve. Preferably, the rod 34 OD is on the order of 3/8" to 3/4" diameter (three eighths to three quarters of an inch diameter), leaving an annulus 60 space between the circumference of the rod 34 and the inner surface of the sleeve 58 nominally on the order of 1/16" (one sixteenth of an inch) within which the lubricant is maintained. In such configuration, a rod speed of greater than 3400 rpm can be maintained from a surface motor through the rod 34 and pump 26. The lubricant in the annulus, as bounded by the

inner surface of the sleeve 54, prevents excursion of mass imbalanced portions of the drive rod 34, by absorbing energy where such conditions exist and forming a lubricated, damped physical barrier against significant physical movement of the rod 34 in a radial direction. Thus the drive rod 34 cannot achieve a high energy self-destructive state because it cannot deform into a significant arch, or whirling position, as was found in the prior art. Drive rod 34 as well as sleeve 54 may be configured as multiple sections of individual lengths to form the full length thereof.

[0024] Referring to Figure 4, there is shown the interrelationship of the various elements at the wellhead 12. Specifically, recovery tube 50 is suspended from a platform 70, such as by providing a flange 72 at the uppermost end 74 thereof, and bolting or otherwise connecting the flange 72 to the platform. The length of the recovery tube 50 and height of the platform 70 thus dictate the position of the pump 26 at the wellbore end of the tube 50. Sleeve 54 extends slightly outwardly of tube 50, and likewise includes a sleeve flange 76, which extends over flange 72 of tube 50 and is connected thereto such as by fasteners. Positioned above tube flange 72 and supported on platform 70 by a bracket 78 is pump motor 80. Motor 80 includes connection to a source of power, preferably electricity, and an output shaft 82 terminating in a drive flange 84. Pump main drive rod 34 extends upwardly from the sleeve 54 through seal 64, which seals the annulus 60, and terminates in a rod flange 88 which mates with, and is bolted to, output shaft flange 84. At a portion of tube 50 located intermediate of the flange 72 and the earth 90 there is provided an outlet 92 through the tube 50, from which piping and a valve may be provided to control the output of well fluids from the annulus 98 between the tube 50 and sleeve 54.

[0025] In operation, well fluids collect in production zone 18, where they are exposed to inlet of lowestmost pump housing 28. Pump motor 80 rotates its output shaft 82, and thus rod 34, at a rotational speed on the order of over 3400 rpm. This rotation is imparted to the input shaft of the uppermost impeller 32, and by virtue of the ganged connection of all pump impellers, causes each pump impeller to rotate at the main drive rod 34 rotational speed. Well fluids are thus accelerated through

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each pump housing by its respective rotor, and thence into the annulus between tube 50 and sleeve 54 to propel the fluids to the well head 12, where they are recovered through outlet 92. Thus, well fluids may be pumped with a centrifugal pump, without the need for locating the motor in a downhole location, and, without the need for reducing and stepping gearboxes, if the motor is located in an easily accessible surface location.

[0026] While the foregoing is directed to embodiments of the present invention, other and further embodiments of the invention may be devised without departing from the basic scope thereof, and the scope thereof is determined by the claims that follow.